Ph. D. Qualifying Examination

Thermodynamics

Fall 2017

Logistics Notes:

- Duration: 2.5 hours.
- Open book (the textbook provided during the exam).
- Calculator is allowed.
- Laptops, cell phones, and similar electronic devices are not allowed.
- State your assumptions.

Problem 1 (30 points): A quantity of air undergoes a Carnot power cycle. At the beginning of the isothermal expansion, the temperature is 290°C and the pressure is 9 bars. At the beginning of the isothermal compression, the temperature is 90°C and the pressure is 0.1 bar. Employing the ideal gas model, determine

1) the pressure at the end of the isothermal expansion and compression processes, each in bars. Draw sketches of T-S and p-v plots for the cycle.

2) the heat added and the net work developed per cycle, each in kJ per kg of air.

3) Evaluate the thermal efficiency.

Problem 2 (60 points): A counterflow heat exchanger (Fig. 1) operates at steady state with negligible kinetic and potential energy effects. In one stream, liquid water enters at 11°C and exits at 25°C with a negligible change in pressure. In the other stream, Refrigerant 134a enters at 12 bar, 130°C with a mass flow rate of 140 kg/h and exits at 12 bar, 30°C. The liquid water can be modeled as incompressible with $c = 4.179$ kJ/(kg · K). Heat transfer between the outer surface of the heat exchanger and environment is negligible. Determine

(a) The mass flow rate of the liquid water in kg/h
(b) The rate of entropy production within the heat exchanger, in kW/K.
(c) Comment whether such a device is possible.

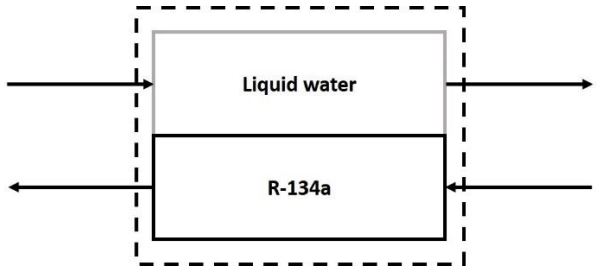

Fig. 1: A counterflow heat exchanger.

Problem 3 (10 points): Water in a piston-cylinder assembly initially at a temperature of 96.71°C and a quality of 80% is heated at constant pressure to a temperature of 200°C. Changes in potential and kinetic energy are negligible. If the work during this process is 350 kJ, determine

(a) the mass of water in kg,
(b) the heat transfer in kJ.
(c) Draw the process on the p-v diagram.